

PRINTHEADS HAVING IMPROVED HEATER CHIP CONSTRUCTION

Field of the Invention:

The invention relates to heater chips for ink jet printers and specifically to print
5 heads having improved heater chip construction.

Background:

Ink jet technology continues to be improved in order to increase printing speed
and print quality or resolution. One means for improving print speed and quality is to
increase the number of nozzle holes in an ink jet print head and to decrease the diameter
10 of the nozzle holes. However, improvements in print speed and quality often result in
operational problems not experienced with lower quality slower speed printers.

In an ink jet printer, ink is provided to the print head from an ink cartridge
or supply tank. The ink flows from the tank through a connecting conduit from
the ink cartridge through an ink via in a semiconductor chip or around the edges
15 of a semiconductor chip and into ink flow channels and an ink chamber. Each
ink chamber is situated in axial alignment with a corresponding nozzle hole and a
heater resistor defined on the surface of the semiconductor chip. Electrical
impulse energy applied to an ink ejector adjacent an ink chamber causes ink
adjacent the ejector in the chamber to be forced through a nozzle hole onto a print
20 medium. By selective activation of a plurality of ink ejectors on a print head, a
pattern of ink dots are applied to the print medium to form an image.

Conventional ink jet print heads desire improvement, particularly with regard to
the manufacture of heater chips for use with print heads. Particularly desired
improvements in the manufacture of heater chips include improvements in the planarity
25 of such chips and in the uniformity of the planarizing layer thickness. Defects in
conventional chips result in print heads that are prone to misdirected ink drop ejection,
poor nozzle plate adhesion, and reduced corrosion resistance.

Ink jet print heads typically include a print head body containing a
semiconductor substrate and a nozzle plate attached to the substrate. The
30 substrate/nozzle plate assembly is received by a chip pocket in the print head body. Ink
is supplied to the substrate/nozzle assembly from an ink reservoir in the print head body
generally opposite the chip pocket. The semiconductor substrate for a thermal print
head is typically a silicon substrate containing a plurality of ink ejection devices such

heater resistors formed on a device side thereof. These substrates are referred to as “heater chips.”

Fig. 1 shows a portion of a prior art heater chip 10 having a plurality of heater resistors 12 formed on a device side 14 thereof. A nozzle plate 16 (Fig. 3) having ink ejection nozzle holes 18 corresponding to the heater resistor sites is generally attached to the chip 10. The device side 14 of the chip 10 also includes conductors 17 from one side of the heater resistors 12 to driver circuitry 19 for supplying electrical impulses from a printer controller to activate the heater resistors 12 for printing. A conductor 21 is connected from the opposite side of the heater resistors 12 to a common power conductor 23. Upon activation of the heater resistors 12, ink supplied through an ink via 20 in the chip 10 is caused to be ejected toward a print media through the nozzle holes 18 (Fig. 3). The chip 10 is configured for use with a top-shooter type print head, wherein the ink is ejected from the nozzle plate 16 attached to the device side 14 of the chip 10.

With reference to Figs. 2A-2B and 3, the chip 10 contains various layers such as a first conductive metal layer 22, a passivation layer 24, and a cavitation protection layer 26 deposited on the device side 14 thereof. The resistors 12 and 33 are defined by a resistive layer 25 and each heater resistor 12 and 33 corresponds to one of the nozzle holes 18 in the nozzle plate 16 for heating and ejecting ink toward a print media. As will be noted, there is a significant topographical variation 27 adjacent end 28 of the heater array.

Fig. 3 shows the nozzle plate 16, not to scale, attached to the heater chip 10. The topographical variation 27 complicates attachment of the nozzle plate 16 and results in a deformation in the orientation and shape of the nozzle hole 18, particularly near orifice 30 of the nozzle hole 18. Deformation of the shape of the nozzle hole 18 results in an ink ejection path, represented by the arrow 32, which deviates from the desired ink ejection path, represented by arrow 34. The angle of the desired but previously unachievable path 34 relative to the resistor is preferably about 90 degrees. The angle represented by the intersection of arrows 32 and 34 in Fig. 3 is exaggerated to illustrate deviation from an ideal ejection path. The angle of the path 32 typically achieved generally ranges from about 90 to about 90.6 degrees. Although a 0.6° deviation from ideal may appear to be minor, the resulting droplet misplacement is significant given the

distance the droplet travels before impacting the recording medium and the high placement precision required for quality printing.

As will further be noted, the heater resistor 33 at the end 28 of a heater array 35 tends to have a relatively higher current path resistance, and hence different energy, than
5 the interior heater resistors 12. This higher resistance results from the availability of only a single current path through the heater resistor 12 adjacent the end 28 of the heater array 35, as represented by arrows 36.

Accordingly, there is a continuing need for improved ink jet printheads as printing speed and print resolution continue to increase. There is also a need for
10 improved methods for making high resolution ink jet printheads.

Summary of the Invention:

With regard to the foregoing, the invention relates to a heater chip for an ink jet print head, to ink jet print heads incorporating such chips, and to methods for making
15 such chips. In a preferred embodiment, the chip includes a substrate having a device side including an active heater array located on the device side having a plurality of active heater resistors that may be placed in electrical communication with a driver circuit for supplying electrical impulses to activate the heater resistors for printing, the active heater array terminating to define an end of the active heater array. An inactive
20 heater array is located adjacent to and extending away from the end of the active heater array.

The inactive heater array provides a region adjacent the end of the active heater array that is substantially planar, and also provides a plurality of current paths which reduce energy differences in heaters resistors adjacent the end of the active heater array
25 when compared to other heater resistors in the heater array.

The present invention provides an improved heater chip construction that achieves a number of specific advantages over conventional heater chips and print heads. For example, the invention enhances the planarity of the chip and reduces the energy difference between heater resistors adjacent the end of a heater array, resulting in
30 improved print head performance and life. Enhanced planarity is achieved by including an additional, but inactive, heater structure adjacent the end of the active heater array. The inactive heater structure serves to relocate the abrupt topographical variations sufficiently remote from the end of the active heater array. Reduced topographical

variations facilitate attachment of a nozzle plate to the chip in a manner that improves nozzle plate adhesion and also reduce distortion of ink ejection paths through nozzle holes in the nozzle plate. The improved planarity also results in an increased thickness of the planarizing layer on the chip adjacent the end of an active heater array, thereby
5 improving corrosion resistance of the active heater array structure.

The inactive heater structures also increase the available current paths, thereby decreasing the energy difference of heater resistors adjacent the end of the heater array compared to other heater resistors in the heater array. A reduction of the energy difference achieved by the chip construction helps provide more consistent heater
10 resistor energy characteristics, resulting in improved ink bubble performance and print performance.

Brief Description of the Drawings:

The above and other aspects and advantages of the invention will become further
15 apparent by reference to the following detailed description of preferred embodiments when considered in conjunction with the accompanying drawings in which:

Fig. 1 is a plan view, not to scale, of a prior art chip layout;

Fig. 2A is a partial plan view, not to scale, of a portion of the prior art chip layout of FIG. 1;

20 Fig. 2B is a partial cross-sectional view, not to scale, along lines 2B-2B of Fig. 2A of a prior art chip;

Fig. 3 is a representational cross-sectional view, not to scale, of a prior art heater chip illustrating a nozzle plate bonded thereto;

Fig. 4 is a plan view, not to scale, of an improved chip layout in accordance with
25 a preferred embodiment of the invention;

Fig. 5A is a partial plan view, not to scale, of a portion of the improved chip layout of FIG. 4;

Fig. 5B is a partial cross-sectional view, not to scale, along lines 5B-5B of the improved chip layout of FIG. 4;

30 Fig. 6 is a representational cross-sectional view, not to scale, of an improved heater chip according to the invention and illustrating a nozzle plate bonded thereto.

Detailed Description of the Preferred Embodiments:

The present invention provides an improved heater chip having one or more inactive heater structures, such as inactive heater resistors, located adjacent the end of the active heater array. Use of inactive heater resistors advantageously shifts abrupt topographical variations away from the end of the active heater array so that the
5 topographical variations have considerably less impact on a nozzle bore angle and ink droplet trajectory. The inactive heater resistors also increase the available current paths, thereby decreasing the energy difference between heater resistors adjacent the end of the heater array and other heater resistors in the heater array.

In a preferred embodiment, and with reference to Fig. 4, the invention provides a
10 heater chip 50 having a heater array 51 containing a plurality of active heater resistors 52 formed on a device side 54 thereof. A nozzle plate 56 (Fig. 6) having ink ejection nozzle holes 58 corresponding to the active heater resistor sites is generally attached to the chip 50. The device side 54 of the chip 50 also includes conductors 53 from one side of the active heater resistors 52 to driver circuitry 59 for supplying electrical
15 impulses from a printer controller to activate the heater resistors 52 for printing. The opposite side of the active heater resistors 52 is connected by conductor 55 to common power conductor 57. Upon activation of the active heater resistors 52, ink supplied through an ink via 60 in the chip 50 is caused to be ejected toward a print media through the nozzle holes 58. The chip 50 as shown is configured for use with a top-shooter type
20 print head wherein ink is ejected from the nozzle plate 56 attached to the device side 54 of the chip.

One or more inactive heater resistors 62 is provided on the chip 50 beginning at a location adjacent end 64 of the array 51 of the active heater resistors 52 and continuing in a direction away from end 64 of the array 51 of active heaters 52. For a heater chip
25 50 having at least about one hundred of the active heaters 52 defining the active heater array 51, it is preferred to provide from about one to about four of the inactive heater resistors 62.

The overall dimension of the chip 50 preferably ranges from about three to about seven millimeters wide by from about eight to about seventeen millimeters long, and is
30 about 0.6 millimeters thick. The via 60 is preferably provided by a single slot or a plurality of openings in the chip 50 made by a dry etch process and having an overall dimension of from about 0.2 to about 0.4 millimeters wide by from about four to about thirteen millimeters long. It will be appreciated that other inactive structures may be

used in place of inactive heater resistors 62 to provide the benefits of the invention described in more detail below.

With reference to Figs. 5A and 5B, the chip 50 preferably contains various layers such as conductive metal layer 72, passivation layer 74, and cavitation protection layer 76 deposited on the device side 54 thereof. The active resistors 52 and 84 are defined in a resistive layer 75 and each active heater resistor 52 corresponds to one of the nozzle holes 58 in the nozzle plate 56 for heating and ejecting ink toward a print media. The inactive heater resistors 62 are preferably formed in the same manner and at substantially the same time as the active heaters 52 and 84, except that they are not connected to the driver circuitry 59.

Fig. 6 shows the nozzle plate 56 attached to the heater chip 50. As will be noted, topographical variation 77 is less abrupt as compared to the topographical variation 27 shown in Fig. 3, and the most abrupt portion of the variation 77 is shifted away from the end 64 of the active heater array 51 such that a region 79 adjacent the end 64 of the active heater array 51 is substantially planar. This facilitates attachment of the nozzle plate 56 to the chip 50 and advantageously avoids any significant deformation in the orientation and shape of the nozzle hole 58, achieving an ejection path, represented by the arrow 80 that is significantly more desirable than the path 32 discussed in connection with Fig. 3 and substantially corresponds to the desired path 34.

The resulting topography of the chip 50, which is substantially more planar than the topographies of prior chips, particularly with respect to the regions 78 immediately adjacent the end 64 of the active heater array 51, also advantageously enables deposition of a more planar and consistent passivation and cavitation layers, resulting in improved chip performance and life. For example, it has been observed that passivation and planarizing layers, such as those provided by depositing a photoresist of the type useful for inhibiting corrosion of the print head components, have improved consistency and planarity, resulting, among other things, in improved corrosion resistance.

As will further be noted, the inclusion of the inactive heater resistors 62 at the end 64 of the active heater array provides a plurality of current paths, as represented by arrows 82 (Fig. 4). This advantageously reduces the current path resistance, and hence reduces the energy differences between heater resistors 84 adjacent the end 64 of the heater array and other heater resistors 52 in the heater array 51. This helps to provide

more consistent energy characteristics for the region of the active heaters 52 and 84 and improves ink bubble performance and print performance.

The foregoing description of certain exemplary embodiments of the present invention has been provided for purposes of illustration only, and it is understood that
5 numerous modifications, alterations, substitutions, or changes may be made in and to the illustrated embodiments without departing from the spirit and scope of the invention.